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Implant Production using Selective Laser Melting

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«Photonics 4 Precision Manufacturing»

SALON INTERNATIONAL
LEADER DE LA HAUTE PRECISION
HORLOGERIE-JOAILLERIE • MICROTECHNOLOGIES • MEDTECH

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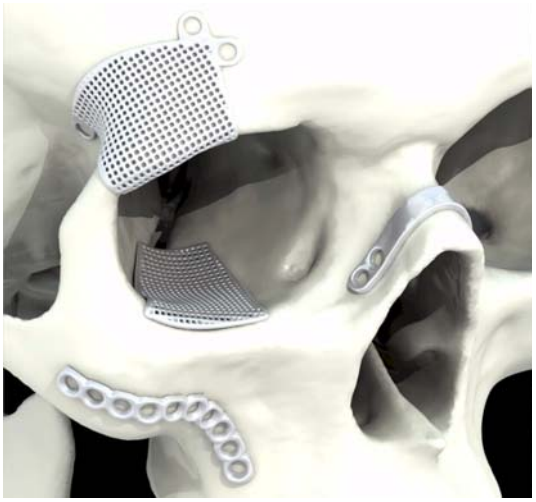
Overview

- **smart implants:** patient-specific implants
- **smart shape:** shape memory implants
- **smart material:** resorbable materials

Open-porous shape memory implants for temporary or permanent bone replacement



virtual representation

physical representation

R. Schumacher, M. de Wild, S. Fabbri, A. Yildiz, E. Schkommodau, *Rapid Manufacturing of Individualized Ti-6Al-4V Bone Implants*, European Cells and Materials Vol. 17/22, 1 (2009).

R. Schumacher, M. de Wild, E. Schkommodau, D. Hradetzky, *Massgeschneiderte Knochenimplantate aus dem 3D-Drucker*, BaZ-Sonderbeilage "Life Sciences" vom 12. Mai (2012).

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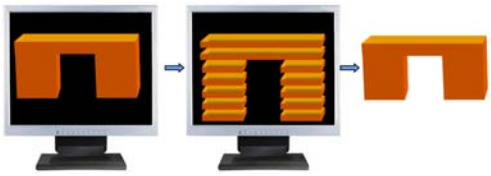
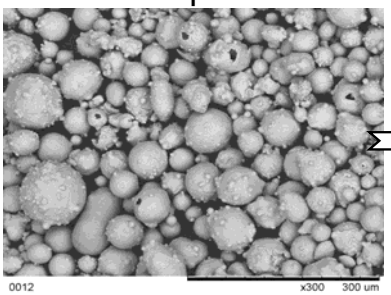
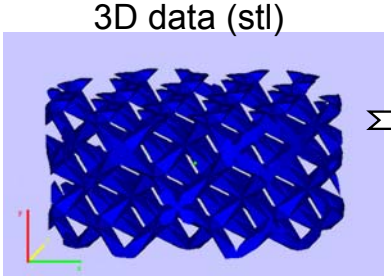
Fabrication of implants by Selective Laser Melting



metall powder



3D data (stl)



Post processing if necessary (e.g. heat treatment, etching)

Processing parameters

Bormann T. *et al*., eCells Mater 20 (Suppl 1): 13, 2010.

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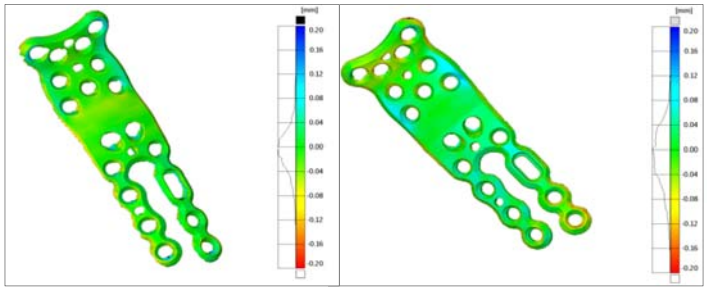
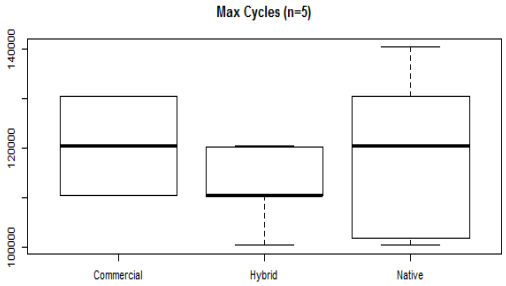
Individualized implants for temporary or permanent bone replacement

Left: Medartis® wrist fusion plate spanning the radio-carpal and mid-carpal joint. Right: SLM replica.



Geometrical accuracy check. Left: before heat treatment. Right: after heat treatment.

medartis®



Fatigue test: Comparison between commercially machined plates and SLM plates.

R. Schumacher, P. Lamprecht, S. Zimmermann, M. de Wild, A. Spiegel,
Comparison of SLM and conventionally produced implants using dynamic biomechanical loading, RapidTech Erfurt, 2013.

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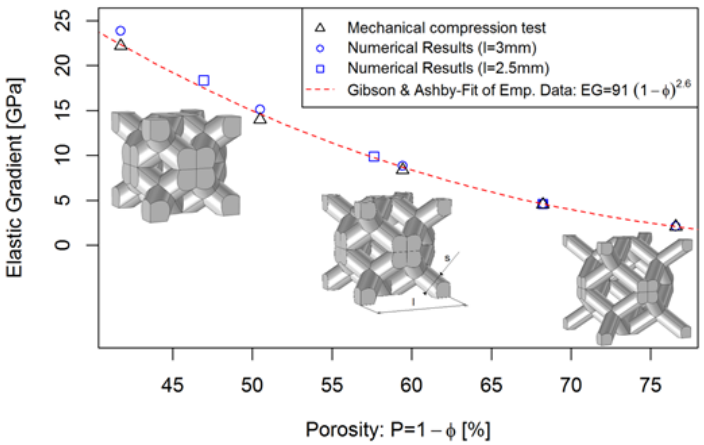
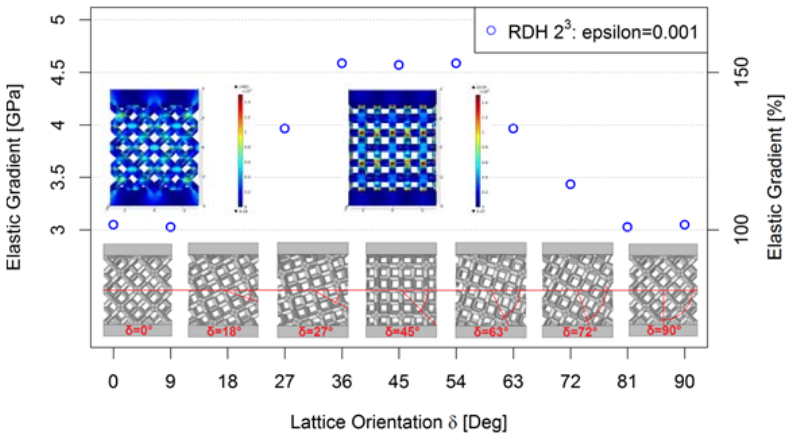
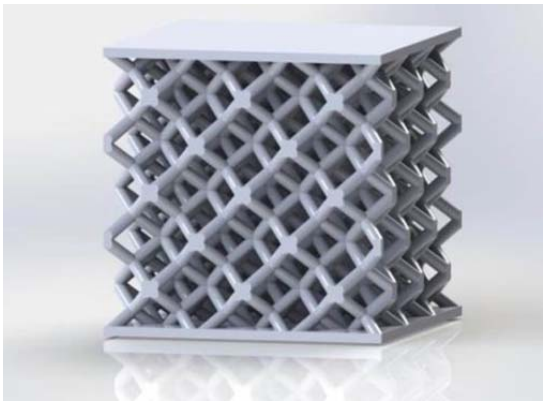
Functional lattice structures: adapted stiffness





S. Zimmermann, M. de Wild, *Density- and Angle-Dependent Stiffness of Titanium 3D Lattice Structures*, BioNanoMat 15 (S1), S35, (2014).



Schumacher R., et al. *Specific design of bone grafts according to Hounsfield units*. DGBMT Freiburg 2011.

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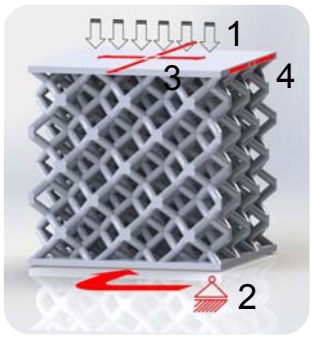
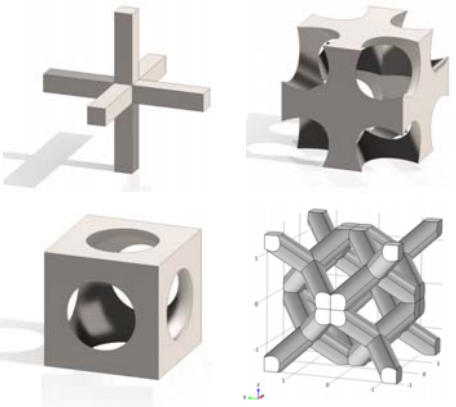
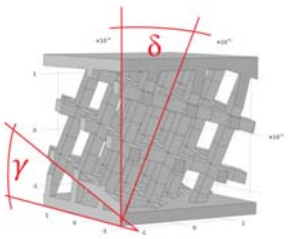
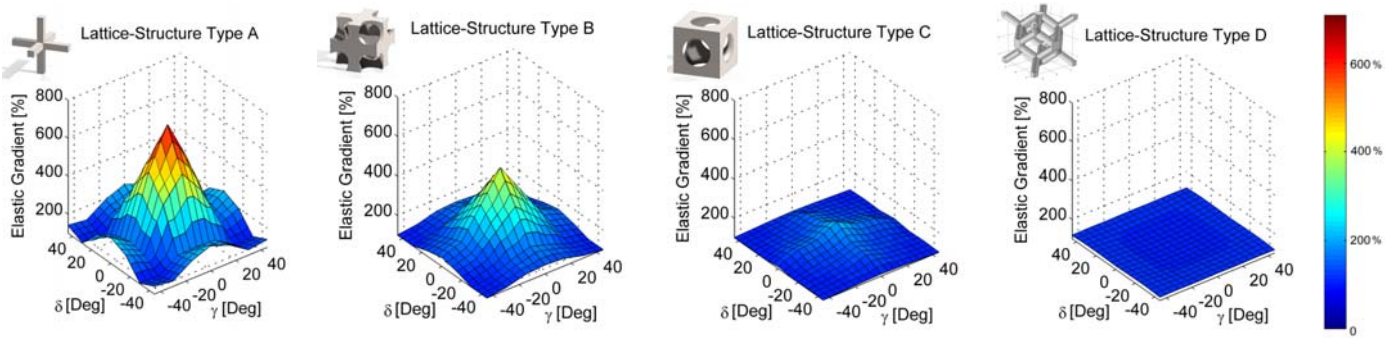
Stiffness-anisotropy of porous implant geometries





Lattice Type	Porosity	Elastic Anisotropy
A	0.83	700%
B	0.76	450%
C	0.71	200%
D	0.73	120%





S. Zimmermann, F.E. Weber, R. Schumacher, J. Rüegg, M. de Wild,
stiffness-anisotropy of porous implant geometries, European Cells and Materials, 29, Suppl. 2, 22 (2015).

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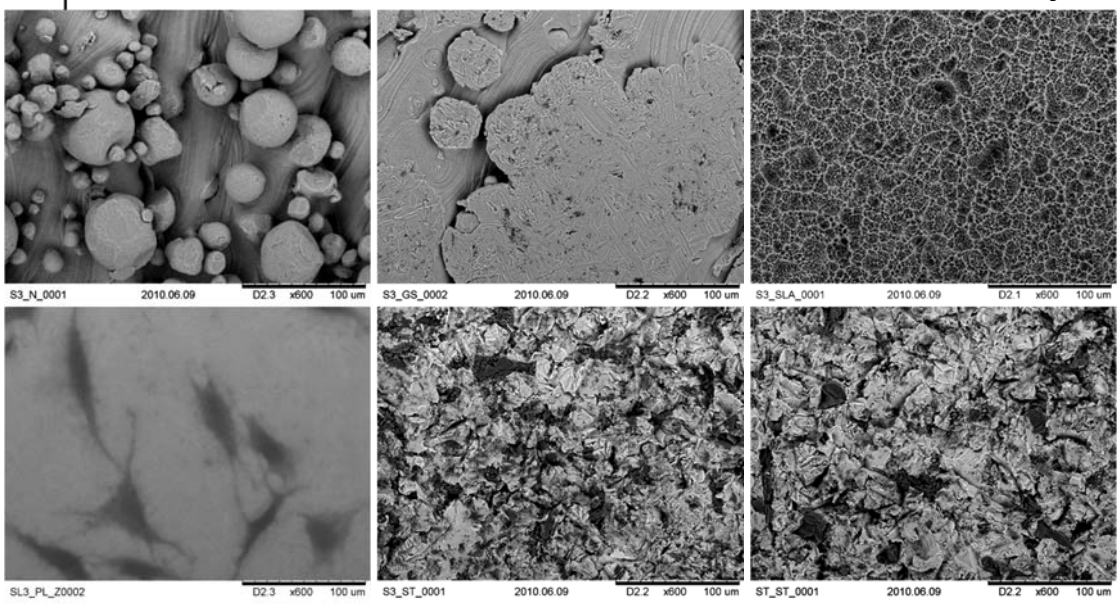
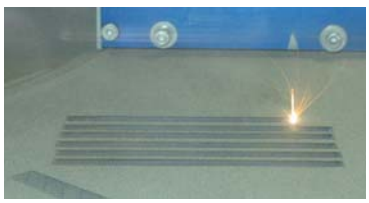
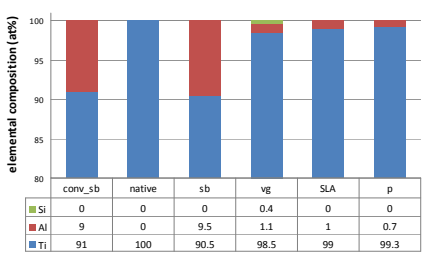
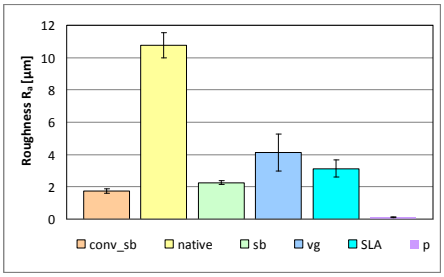
Cytocompatibility



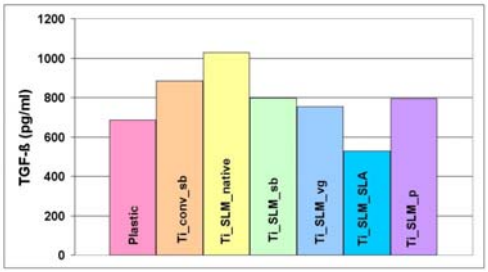




Roughness analysis.



EDX elemental analysis.



TGF-β expression of MG63 cells on different surface topographies after 14 days.

M. de Wild, et al, *Surface Modification and In-vitro Investigation of Generatively Produced Implants*, Biomaterialien, 11, 157 (2010).

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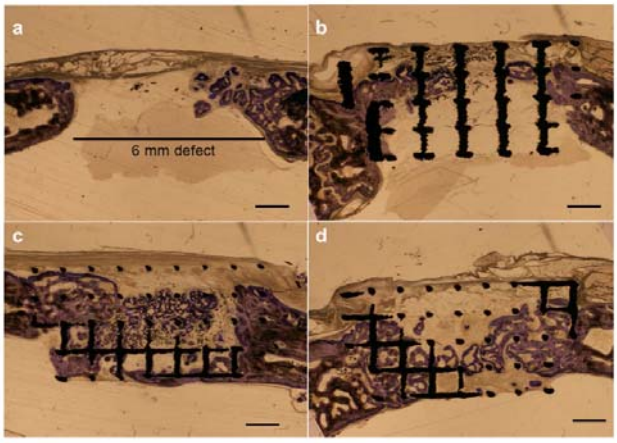
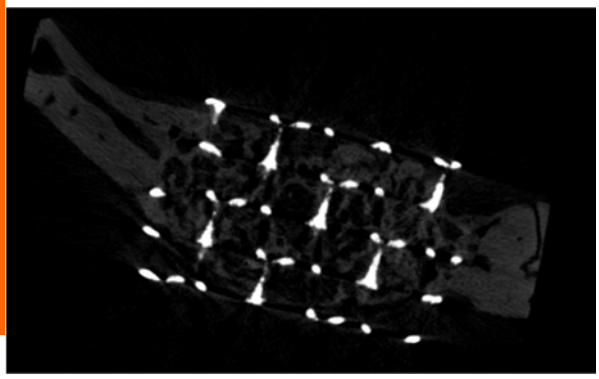
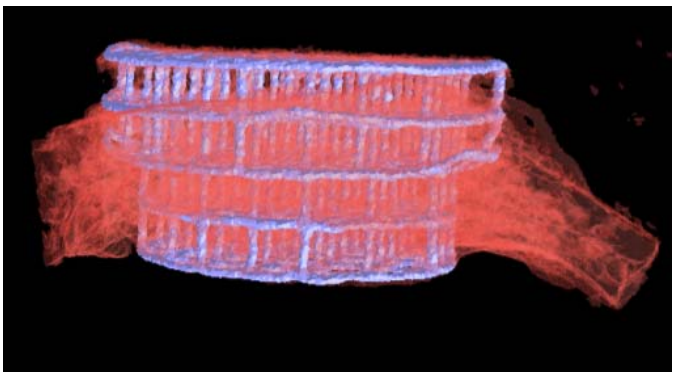


porous cpTi implants





M. de Wild, R. Schumacher, K. Mayer, E. Schkommodau, D. Thoma, M. Bredell, A. Kruse, K.W. Grätz, F.E. Weber, *Bone regeneration by the osteoconductivity of porous titanium implants manufactured by selective laser melting: A histological and µCT study in the rabbit*, Tissue Engineering Part A, 19(23-24):2645-54 (2013).

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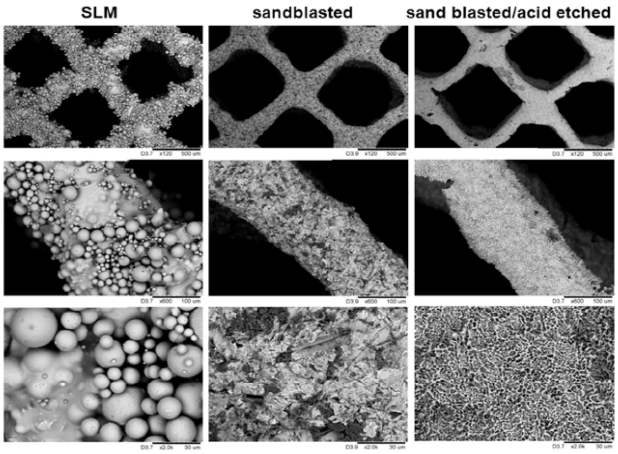

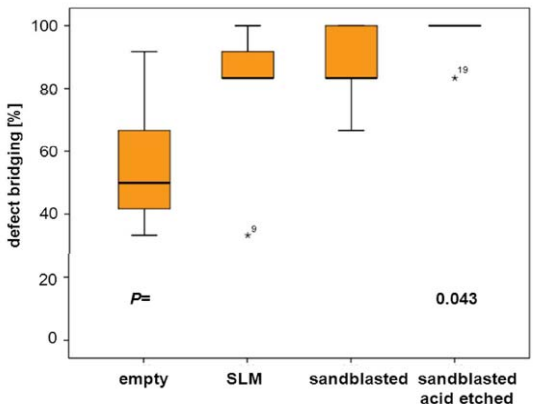

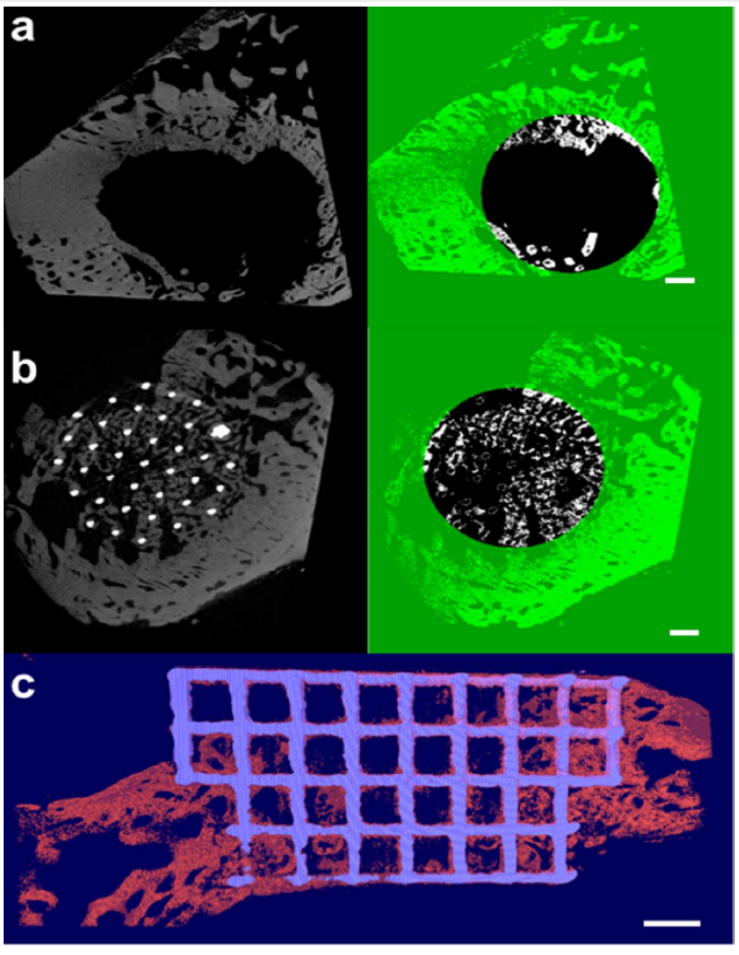

M. de Wild, R. Schumacher, K. Mayer, E. Schkommodau, D. Thoma, M. Bredell, A. Kruse, K.W. Grätz, F.E. Weber, *Bone regeneration by the osteoconductivity of porous titanium implants manufactured by selective laser melting: A histological and µCT study in the rabbit*, Tissue Engineering Part A, 19(23-24):2645-54 (2013).

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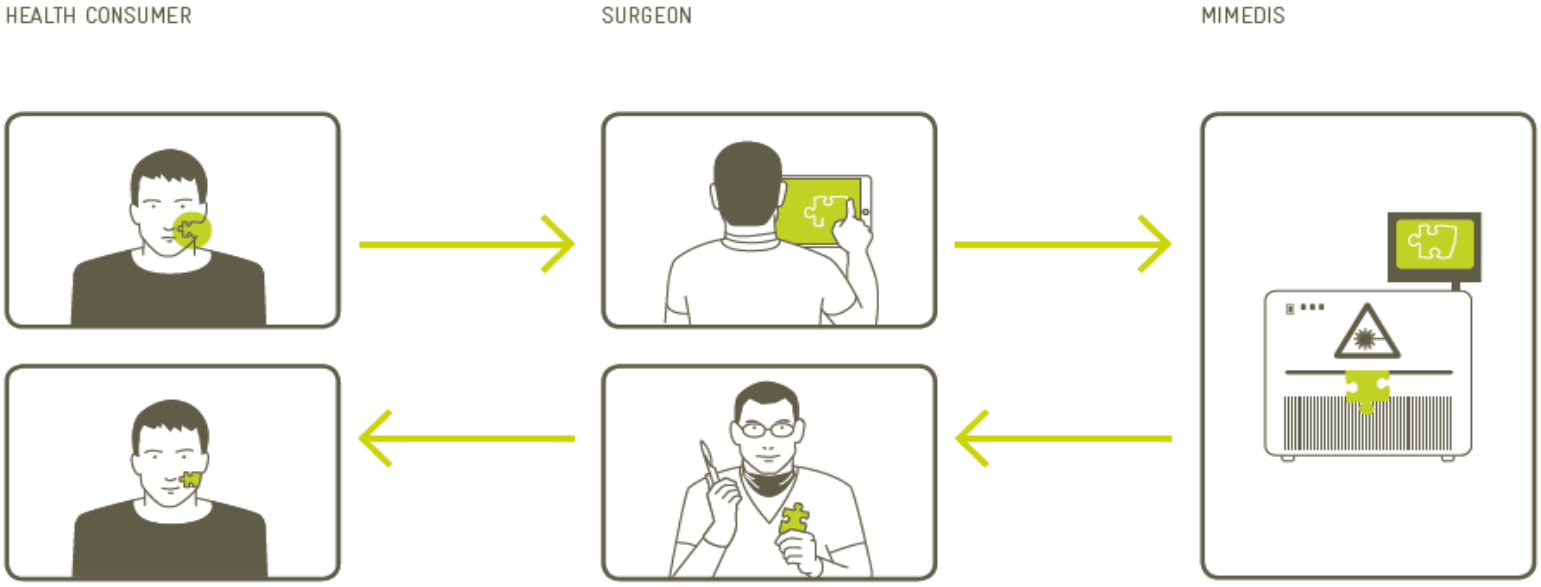
MIMEDIS

freedom to mime anatomy



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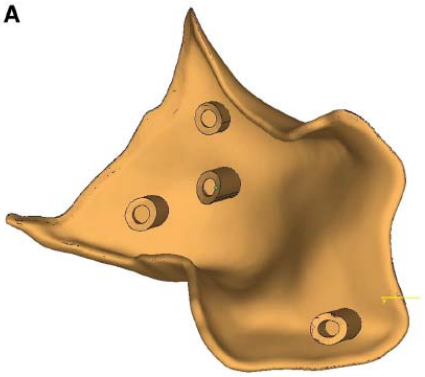
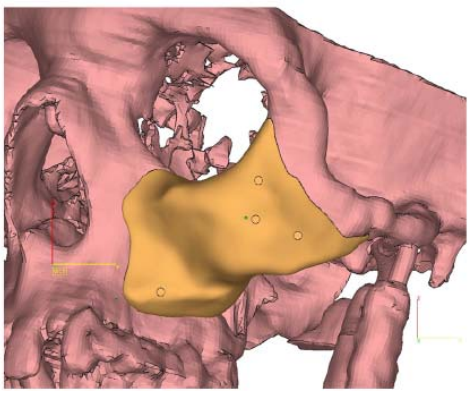
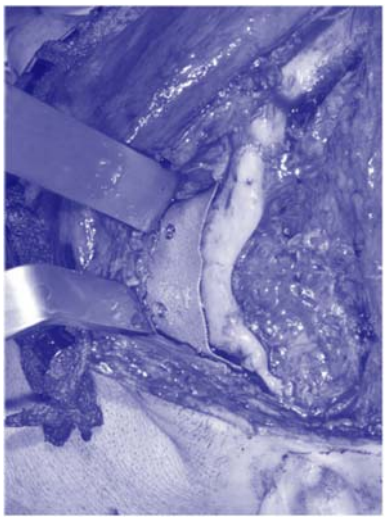
trauma event during which the bone segments were lost





The virtual zygoma implant. (A) Internal side with fixation rods. (B) Position on the skull.



Intraoperative placement and fixation of the implant using 2.0-mm titanium lag-screws(arrows).

Postoperative axial CT scan showing the restoration of the symmetry of the zygomatic bone.

Rotaru et al., *Selective laser melted titanium implants: a new technique for the reconstruction of extensive zygomatic complex defects*, Maxillofacial Plastic and Reconstructive Surgery (2015) 37:1

Overview

- **smart implants:** patient-specific implants
- **smart shape:** shape memory implants
- **smart material:** resorbable materials

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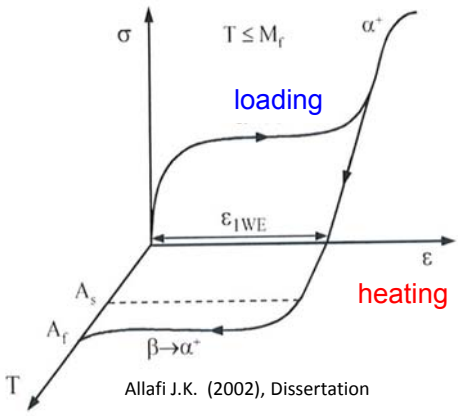
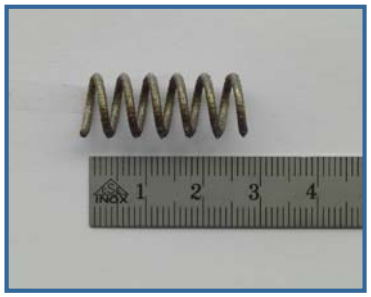
we support your innovation
MEMRY

The shape memory effect of SLM-NiTi

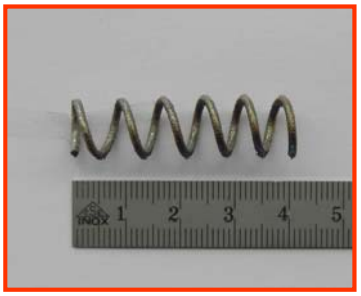
http://www.tradekorea.com/products/spinal_implant.html



Allafi J.K. (2002), Dissertation



SLM fabricated sample



Elongated sample

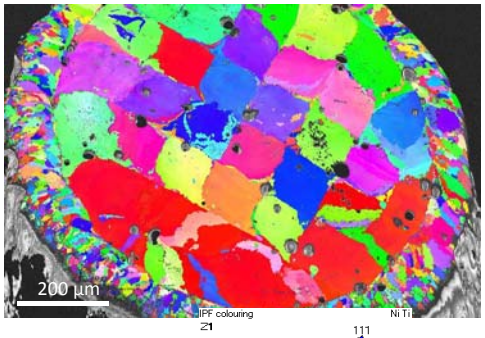
Sample after heating

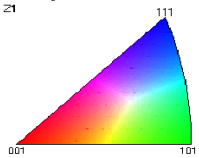
Therese Bormann, et al., *Determination of strain fields in porous shape memory alloys using micro computed tomography*, Proc. of SPIE Vol. 7804 78041M-1-9 (2010).

Microstructure depending on scanning strategy

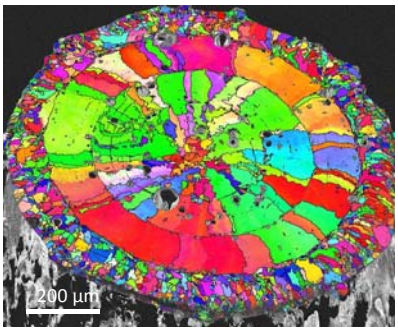
x-y-plane

d = 120 µm

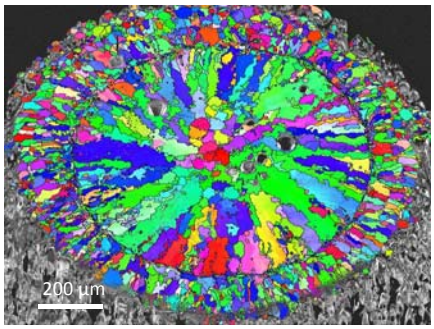




d = 120 µm



d = 60 µm



→ Electron backscatter diffraction reveals grain orientation (Cooperation with ETHZ).

T. Bormann, F. Beckmann, M. Schinhammer, H. Deyhle, M. de Wild, B. Müller, *Assessing the grain structure of highly X-ray absorbing metallic alloys*, Int. J. Mat. Res., 105;7, 692-701 (2014).

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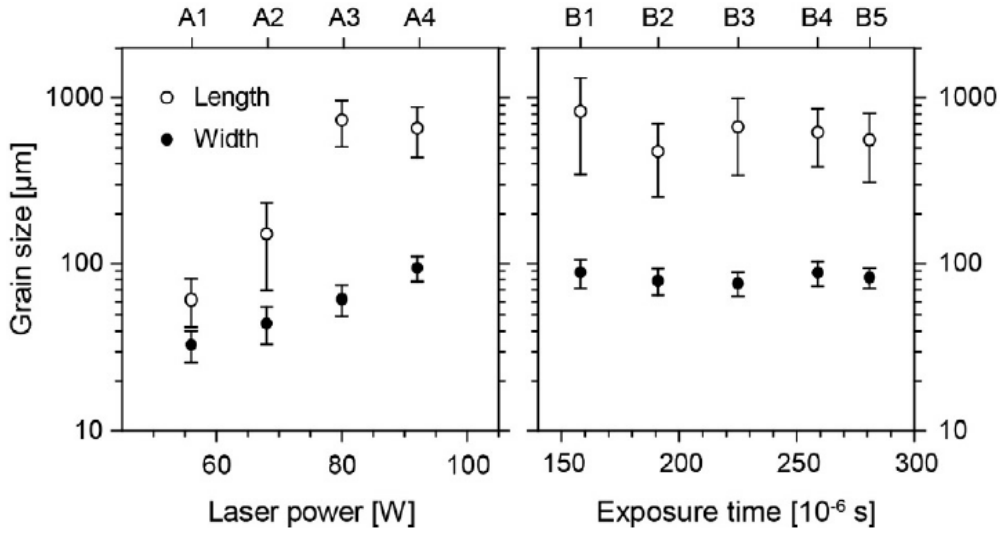
Modify the grain size of NiTi by SLM parameter



T. Bormann, B. Müller, M. Schinhammer, A. Kessler, P. Thalmann, M. de Wild, *Microstructure of selective laser melted nickel-titanium*, Materials Characterization, 94, 189-202 (2014).

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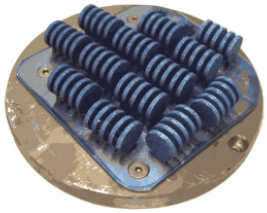
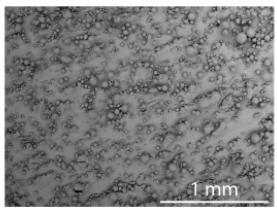
Smart NiTi constructs for 3D cell culture applications

2D

2D disks on building platform

SEM 2D disk



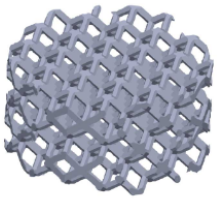


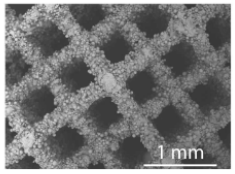
3D

CAD unit cell

CAD scaffold

SEM scaffold

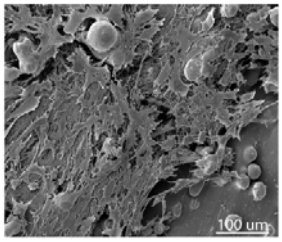


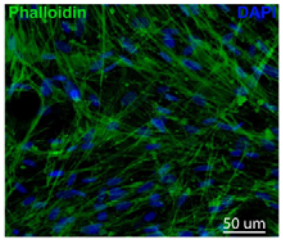


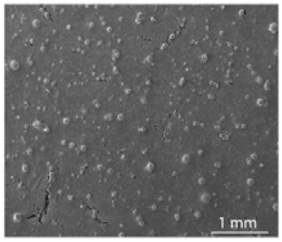
Cell morphology

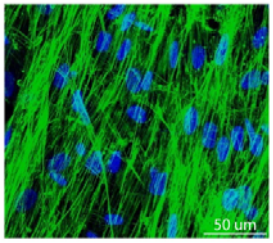
SEM 2D disk

CLSM 2D disk



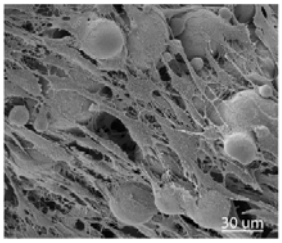


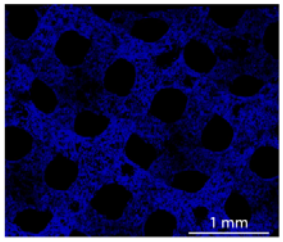


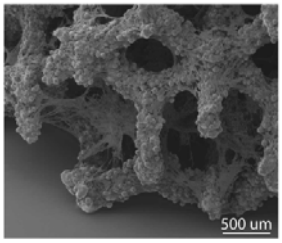


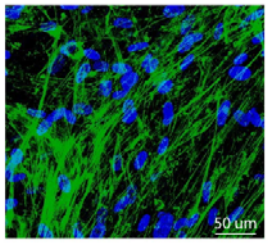
SEM 3D scaffold

CLSM 3D scaffold









W. Hoffmann, F.Schlottig, M.Mertmann, M. de Wild, D. Wendt, I. Martin, *The interplay between NiTi-SMA and human bone marrow-derived mesenchymal stromal cell*, Proceeding p. 46-47 of the 4th International Symposium Interface Biology of Implants IBI, 9.-11. May 2012, Warnemünde/Rostock (Germany).

Overview

- **smart implants:** **patient-specific implants**
- **smart shape:** **shape memory implants**
- **smart material:** **resorbable materials**

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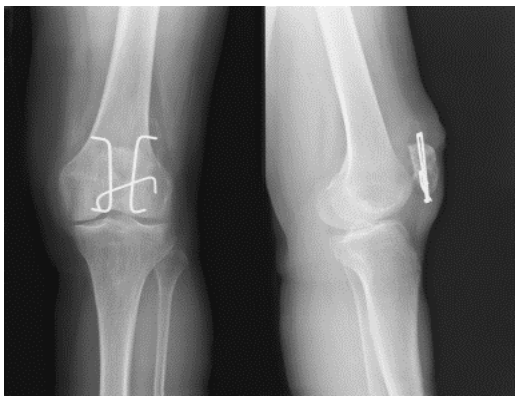
Surgical removal of metal parts



http://www.chirurgie-rottach.de/leistungen/unfallchirurgie/metallentfernung

Fersenbein, Calcaneusfraktur, Osteosynthese

http://pictures.doccheck.com/de/photos/323/16487/calcaneusfraktur-rechts-osteosynthese/

- foreign material
- foreign body reactions
- dislocations
- impaired growth (children)
- injury of tissues
- inflammation
- costs

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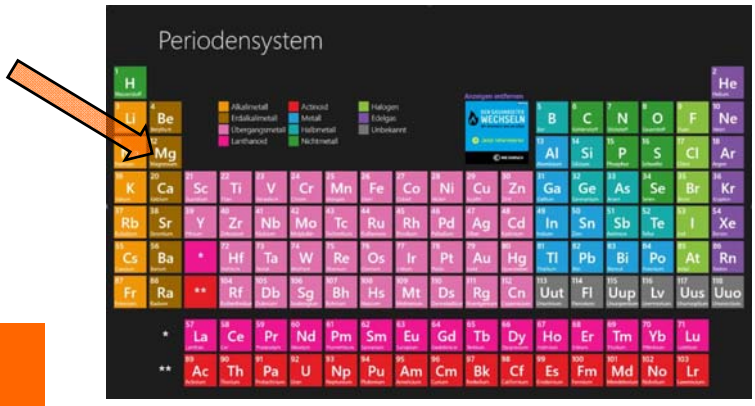

MAGNEZIX® Compression Screw 3.2 for fixation of bone fractures.

http://www.syntellix.de

Cortex Screw manufactured with Mg-Ca alloy

http://www.youic.com

comparison with other biomaterials

property	bone	Mg	Ti	CoCr	steel	HA
density [g/cm^3]	1.8 – 2.1	**1.74 – 2.0**	4.4 – 4.5	8.3 – 9.2	7.9 – 8.1	3.1
E-Modulus [GPa]	3 – 20	**41 – 45**	110 – 117	230	189 – 205	73 – 117
compressive strength [MPa]	130 – 180	**65 – 100**	758 – 1117	450 – 1000	170 – 310	600
toughness [MPa m$^{-1/2}$]	3 – 6	**15 – 40**	55 – 115	k.A.	50 – 200	0.7

M.P. Staiger et al., *Magnesium and ist alloys as orthopedic biomaterials: A review*, Biomaterials, 27, 1728 -1734 (2006).

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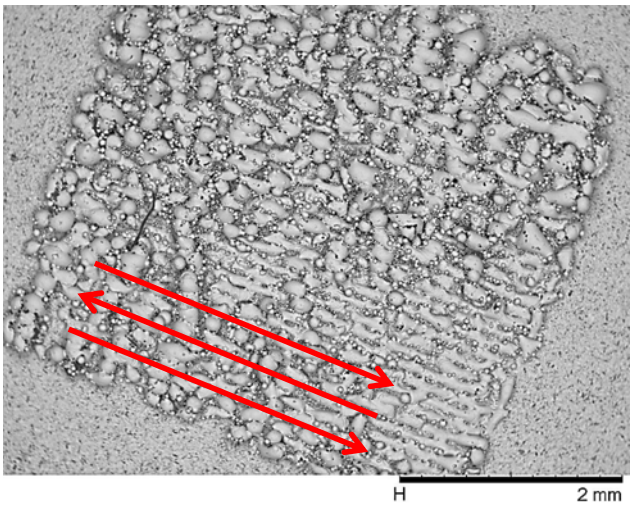
Powder selectively fused to Ti substrate within the recipient



Ti powder

Mg powder

on Ti substrate

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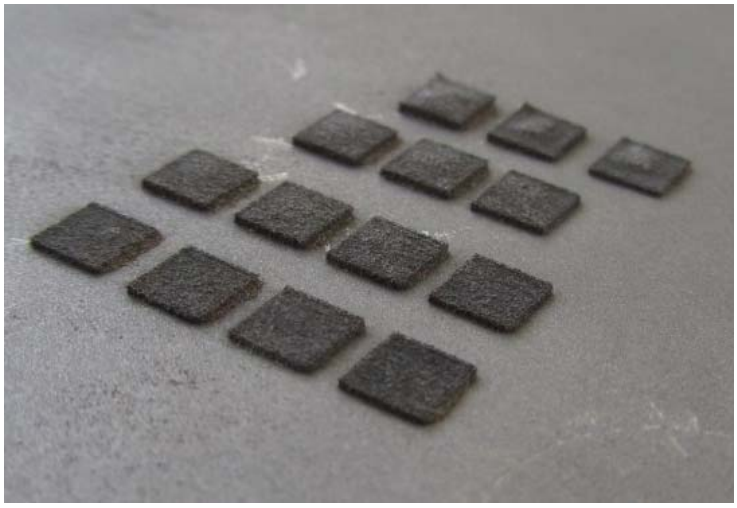
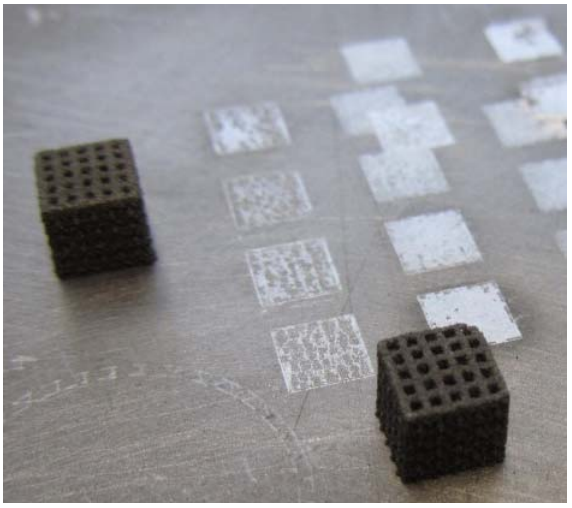
Mg SLM structures

Built inside the safety recipient



Built in the SLM chamber



J. Rüegg, S. Böhringer, A. Kessler, R. Schumacher, E. Schkommodau, M. de Wild,
Degradable Mg scaffolds produced by selective laser melting,
Front. Bioeng. Biotechnol. Conference Abstract: 10th World Biomaterials Congress.
doi: 10.3389/conf.FBIOE.2016.01.00962 Published Online: 30 Mar 2016 (2016).

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Thank you for your attention!